

## RAINFALL EROSIVITY ASSESSMENT –SPATIAL & TEMPORAL VARIABILITY IN ANDHRA PRADESH AND TELANGANA STATES IN INDIA

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### ABSTRACT

*A study was made to estimate the spatial and temporal trends of rainfall erosivity in the erstwhile state of Andhra Pradesh. Daily rainfall data of 1142 stations across the erstwhile states of Andhra Pradesh and Telangana were used to estimate the rainfall erosivity values. Based on this, relationships were established to estimate the rainfall erosivity, when weekly/ monthly yearly rainfall is available. Established a relationship between yearly rainfall erosivity and Fournier Index, a factor considered to be influencing land degradation, to determine the factor of rainfall erosivity in the wider area. Average annual erosivity maps were developed for spatial distribution assessment of erosivity.*

*The study revealed that annual erosivity index ( $EI_{30}$ ) ranges from  $992.97 \text{ t ha}^{-1} \text{ cm h}^{-1}$  at Anantapur in Rayalaseema region to  $2975.4 \text{ t ha}^{-1} \text{ cm h}^{-1}$  at Nellore in Coastal Andhra region. The average annual rainfall erosivity index for erstwhile state of Andhra Pradesh was  $1986.40 \text{ t ha}^{-1} \text{ cm h}^{-1}$ . Average monthly rainfall erosivity factor values showed that the maximum values of rainfall erosivity occur in June to October as the average rainfall also has the maximum values in these months; the highest erosion intensity can be expected during these months. The average annual erosivity factor in rainfall erosion index map was useful to determine the variability in erosivity at different locations in state/districts. It was found that the maximum average annual rainfall erosivity factor ranged from 2950 to  $3450 \text{ t ha}^{-1} \text{ cm h}^{-1}$  for one station and minimum value of 950 to  $1450 \text{ t ha}^{-1} \text{ cm h}^{-1}$  was found in six stations of different districts.*

**KEYWORDS:** Rainfall erosivity, Fournier index & erosivity index

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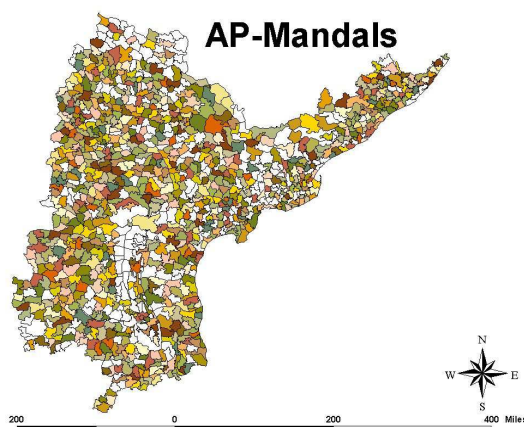
### INTRODUCTION

Universal soil loss equation (USLE) or revised universal soil loss equation (RUSLE) models provide annual or long term erosion hazard estimates for a site depending on knowledge of hourly or sub-hourly distribution of rainfall intensities. Short duration rainfall intensity data are obtained by either digital pluviographs or tipping-bucket technology (discrete rainfall rates) but, in many parts of the world records of this type are still limited in time (Yu et al., 2001). Different indirect models have been proposed for estimating rainfall erosivity at longer time scales (Renard and Freimund, 1994) to overcome this problem. The mean or average values of water erosion indices derived from standard rainfall data, as typically used in a modified Fournier index analysis (Arnoldus, 1977) or in simple relationships of proportionality to rainfall amount (Grimm et al., 2003), are not a good predictor of erosivity (De Ploey et al., 1991; Torri et al., 2006). The numerical value of rainfall and runoff factor (R-factor – rainfall erosivity) are needed for making use of USLE procedure. R-factor represents the climatic influence on soil

erosion. Though it has been suggested to use R-factor derived from long term data, inter annual variability in soil loss could be studied by using R-factor derived from individual year's rainfall. Basic requirement for computation of R-factor is the availability of continuous rainfall data. In the absence of such data, methods need to be developed to estimate the R-value based daily/monthly/annual rainfall values. Establishment of a relation between daily rainfall and  $EI_{30}$  for a single station and extending it to the larger region or the establishment of a relation between R factor and monthly rainfall (known as Fournier index) or the establishment of a relation between R-factor and total annual rainfall in the form of regression equations. The resultant equations are location dependent and also need to be updated for every few years to account for changes in variability, if any, of rainfall. Keeping in view of the above, a study was conducted to develop different relationships to estimate R-value so that daily rainfall (available for a large number of stations) could be used to estimate the annual R - factor and study the spatial trends within the smaller region like district and state. The study also included the temporal trends of R-factor to assess its impact on soil loss. The outcome from this study would be helpful in the estimation of soil loss and modelling/decision support systems in watershed management.

### Study Area

The present study was carried out in the Central Research Institute for Dryland Agriculture (CRIDA) on assessment of rainfall erosivity and its spatial and temporal trends in erstwhile state Andhra Pradesh. Daily rainfall data of 1142 stations spread all over the erstwhile state of Andhra Pradesh for 37 years from 1963 to 1999 were collected from State's Mandal Revenue Departments. The erstwhile state of Andhra Pradesh in India lies between latitude  $12^{\circ} 41'$  and  $22^{\circ}$  N and Longitude  $77^{\circ}$  and  $84^{\circ} 40'$  E. The average annual rainfall is around 911 mm of which 80 percent receives during rainy season between June to September and nearly eight percent receives during the winter season between Octobers to March. The average temperature in summer varies from  $20^{\circ}\text{C}$  to  $40^{\circ}\text{C}$ , whereas in winter, it is between  $13^{\circ}\text{C}$  and  $32^{\circ}\text{C}$ . The map of the study area is given in Figure. 1 indicating 1142 stations spread all over Andhra Pradesh and Telangana states.



**Figure 1: Andhra Pradesh & Telanagana States map indicating 1142 stations**

### Data Collection

The daily five minute interval rainfall data were collected from different automatic weather stations. Precipitation gridded datasets collected from Mandal headquarters were maintained by the revenue department.

### Computation of Five Minutes Interval Intensities

The daily five minute interval rainfall data during 1994 to 1997 were collected from CRIDA, Hayatnagar research farm (HRF) automatic weather station. In HRF, automatic weather station was established in which tipping bucket rain gauge with electronic data logger that records daily five minute interval data. The five minute interval rainfall intensity for 9<sup>th</sup> June 1994 was given below in Table 1

**Table 1: Five Minutes Rainfall Intensity at Hayatnagar during 9<sup>th</sup> June 1994**

Time, h	Duration, min	Rainfall, mm	Time, h	Duration, min	Rainfall, mm
16.40	5	0.254	17.45	5	0.508
16.45	5	3.302	18.00	15	0.254
16.50	5	3.556	18.45	45	0.254
16.55	5	2.794	19.00	15	0.254
17.00	5	3.556	19.05	5	0.254
17.05	5	3.048	19.15	10	0.254
17.10	5	2.54	19.20	5	0.254
17.15	5	2.54	19.25	5	0.254
17.20	5	1.27	19.45	20	0.254
17.25	5	1.778	20.20	35	0.254
17.30	5	1.016	20.30	10	0.254
17.35	5	0.508	20.45	15	0.254
17.40	5	0.254	Total		29.718

### Estimation of 30 Minutes Maximum Rainfall Intensity ( $I_{30}$ )

From the five minute interval rainfall data 30 minutes interval rainfall was noted down. The highest average rainfall intensity in any 30-minute period during the storm was noted down by knowing the maximum amount of rain, which falls in a period of 30-minute and then converting the same in the form of intensity ( $\text{mmh}^{-1}$ ), which is done simply by adding the same amount. The table for computation of thirty minute interval rainfall intensity for 9<sup>th</sup> June 1994 was given below as Table 2. Similar calculations were carried out for Hayatnagar research farm station from 1994 to 1997.

**Table 2: Thirty Minutes Rainfall Intensity at Hayatnagar during 9<sup>th</sup> June 1994**

Time, H	Duration	Rainfall, Mm	Intensity, $\text{Mmh}^{-1}$
(1)	(2)	(3)	(4)
16.40-17.10	30	16.5	33.0
17.10-17.40	30	9.7	19.3
17.40-18.10	30	1.0	2.4
18.10-18.45	35	0.3	0.3
18.45-19.15	30	0.8	1.5
19.15-19.45	40	1.0	1.5
19.45-20.20	35	0.4	0.7
20.20-20.45	25	2.5	6.1

### Estimation of Kinetic Energy

The kinetic energy of the rainfall can be calculated if the size of the raindrops and their terminal velocities are known. As these are variable and are functions of intensities, the kinetic energy is a function of intensity. The kinetic energy was calculated using the following equation as suggested by Brown & Foster (1987).

$$EM = 0.29[1 - 0.72 \text{Exp. } (-0.05 I)]$$

Where

EM = unit kinetic energy of rainfall, MJha-1mm-1.

I = rainfall intensity, mmh-1

Calculation of kinetic energy for five minutes interval rainfall intensity of 9th July 1994 is given in Table 3. Similar calculations were carried out for the HRF station from 1994 to 1997.

#### Computation of $EI_{1440}$

$EI_{1440}$  is the product of kinetic energy and  $I_{1440}$ . Detailed kinetic energy tables were prepared for each storm in accordance with above energy table. The average intensity in centimeter per hour, for the day was worked out by dividing the total rainfall for the day by 24. This was termed as  $I_{1440}$ . The  $EI_{1440}$  values were calculated by the following formula as suggested by Raghunath and Erasmus (1971).

$$EI_{1440} = \frac{KE \times I_{1440}}{100}$$

Where,  $EI_{1440}$  = erosion index for the day,

**Table 3: Calculation of Kinetic Energy for Five Minutes Interval Rainfall**

Time	Duration, min	Rainfall, mm	Intensity, mm h <sup>-1</sup>	Kinetic Energy, mjha <sup>-1</sup> mm	Kinetic Energy, mjha <sup>-1</sup>	Kinetic Energy, t ha <sup>-1</sup>
(1)	(2)	(3)	(4)	(5)	(6)	(7)
16.40	5	0.254	3.048	0.110	0.028	5.616
16.45	5	3.302	39.624	0.261	0.863	173.117
16.50	5	3.556	42.672	0.265	0.943	189.165
16.55	5	2.794	33.528	0.250	0.700	140.420
17.00	5	3.556	42.672	0.265	0.943	189.165
17.05	5	3.048	36.576	0.265	0.781	156.668
17.10	5	2.540	30.480	0.245	0.621	124.572
17.15	5	2.540	30.480	0.245	0.621	124.572
17.20	5	1.270	15.240	0.193	0.245	49.147
17.25	5	1.778	21.336	0.218	0.387	77.632
17.30	5	1.016	12.192	0.176	0.179	35.907
17.35	5	0.508	6.096	0.136	0.069	13.841
17.40	5	0.254	3.048	0.110	0.028	5.616
17.45	5	0.508	6.096	0.136	0.069	13.841
18.00	15	0.254	31.016	0.090	0.023	4.613
18.45	45	0.254	0.338	0.084	0.021	4.312
19.00	15	0.254	1.016	0.091	0.093	18.655
19.05	5	0.254	3.048	0.110	0.028	5.616
19.15	10	0.254	1.524	0.096	0.240	48.144
19.20	5	0.254	3.048	0.110	0.028	5.616
19.25	5	0.254	3.048	0.110	0.028	5.616
19.45	20	0.254	0.762	0.089	0.022	4.413
20.20	35	0.254	0.435	0.085	0.021	4.212
20.30	10	0.254	1.524	0.096	0.024	4.814
20.45	15	0.254	1.016	0.091	0.093	18.655
	250	29.718	369.863	3.927	7.0985	1423.959

#### Computation of Precipitation Index ( $PI_{1440}$ )

The product of the daily rainfall in centimeters and  $I_{1440}$  was then worked out and termed  $PI_{1440}$  as suggested by

Raghunath and Erasmus (1971). This was also termed as  $(P^2/24)$ . Calculation of daily  $PI_{1440}$  values of 1996 year is given in Table 4. Similar calculations were carried out for the HRF station from 1994 to 1999. Calculation of daily  $EI_{1440}$  values of 1994 year was given in table 4 similar calculations were carried out for the HRF station from 1994 to 1999.

**Table 4: Calculation of  $EI_{1440}$**

Julian Day	Rainfall, mm	$I_{1440}$ , $cmh^{-1}$	Kinetic Energy, $tha^{-1}$	$EI_{1440}$ , $tha^{-1}cmh^{-1}$	$PI_{1440}$ , $cm^2h^{-1}$
(1)	(2)	(3)	(4)	(5)	(6)
161	29.718	0.123	1422.250	1.761	0.367
164	1.540	0.006	41.324	0.003	0.001
165	1.300	0.005	36.810	0.002	0.001
166	2.290	0.010	53.360	0.005	0.002
167	0.760	0.003	24.132	0.001	0.000

#### Computation of Relation between Erosion Index ( $EI_{1440}$ ) and Precipitation Index ( $PI_{1440}$ )

The relationship was developed between  $EI_{1440}$  and  $PI_{1440}$  values plotted on graph paper. Then the graph paper showed a straight-line relationship between  $EI_{1440}$  and  $PI_{1440}$  as will be seen from figure 2. As suggested by Raghunath and Erasmus (1971).

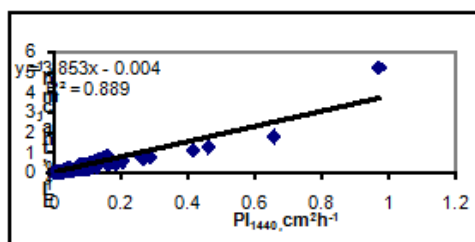
A highly significant correlation  $R^2 = 0.889$  was found to exist between mean annual values of  $EI_{1440}$  and  $PI_{1440}$  and suitable relationship was fitted by least square method.

$$EI_{1440} = 3.856 PI_{1440} - 0.0048 \quad (1)$$

Where

$EI_{1440}$  = erosion index for the day

$PI_{1440}$  = daily precipitation in  $cm^2h^{-1}$



**Figure 2: Relationship between Erosion Index ( $EI_{1440}$ ) and Precipitation Index ( $PI_{1440}$ )**

#### Computation of Erosion Index ( $EI_{30}$ )

Erosion index  $EI_{30}$  is the product of kinetic energy of the storm and the 30-minutes maximum rainfall intensity. It is commonly quantified as R-factor in the Universal Soil Loss Equation (Wischmeier and Smith, 1978). The R-factor is the sum of individual storm erosivity values,  $EI_{30}$ . The  $EI_{30}$  can be calculated by using the following formula as suggested by Wischemeir (1959).

$$EI_{30} = \frac{KEI_{30}}{100}$$

Where

$EI_{30}$  = erosion index

KE = kinetic energy of the storm,  $\text{tha}^{-1}$

$I_{30}$  = maximum 30 minutes intensity of the storm,  $\text{cmh}^{-1}$

Daily  $EI_{30}$  values were calculated for HRF station from 1994 to 1997.

#### Computation of Relation between $EI_{1440}$ And $EI_{30}$

Relationship was also established between  $EI_{1440}$  and  $EI_{30}$  values. This also indicated a statistically significant straight-line trends (Fig.3) as suggested by Raghunath and Erasmus (1971).

$$EI_{30} = 34.065 \times EI_{1440} - 0.2695 \quad (2)$$

Where

$EI_{30}$  = rainfall erosivity at 30 minutes per day

$EI_{1440}$  = erosion index per day

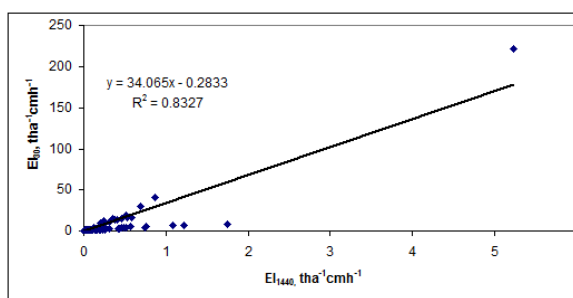


Figure 3: Relationship between  $EI_{30}$  and  $EI_{1440}$

A highly significant correlation  $R^2 = 0.83$  was found to exist between mean annual values of  $EI_{1440}$  and  $EI_{30}$  and suitable relationship was fitted by the least square method. Based on this relationship, the mean annual  $EI_{30}$  values for all the 1142 stations were computed.

Table 5: Calculation of  $EI_{30}$

Julian Day	Rainfall, mm	$I_{30}$ , $\text{cmh}^{-1}$	Kinetic Energy, $\text{tha}^{-1}$	$EI_{30}$ , $\text{tha}^{-1}\text{cmh}^{-1}$
(1)	(2)	(3)	(4)	(5)
161	29.72	33.02	1422.25	46.96
164	1.54	2.57	41.32	0.11
165	1.30	1.59	36.81	0.06
166	2.29	2.03	53.36	0.11
167	0.76	1.52	24.13	0.04

#### Estimation of R Values using Daily Rainfall

The daily rainfall intensity in  $\text{cm}^2\text{h}^{-1}$  for values was put in equation (1) and calculated the  $EI_{1440}$  value. The  $EI_{1440}$  value was then put in equation (2) and calculated the  $EI_{30}$  values. Based on this relationship, the mean annual  $EI_{30}$  values for 1142 stations were computed throughout 37 years.  $EI_{30}$  values can be calculated using the equations (1) and (2) as suggested by Raghunath and Erasmus (1971).

### Estimation of Rainfall and R Values for Weekly Intervals

For obtaining weekly rainfall and EI<sub>30</sub> values, the rainfall and storms EI<sub>30</sub> values for that length of period were added i.e. the rainfall and storms EI<sub>30</sub> values for the length of the weekdays were added as suggested by Raghunath et al. (1982). Weekly values are required to obtain the location differences of erosive rainstorms within the year.

### Estimation of Rainfall and R Values for Monthly Intervals

For obtaining monthly rainfall and EI<sub>30</sub> values, the values of rainfall and EI<sub>30</sub> for that length of period were added i.e. the rainfall and storms EI<sub>30</sub> for the length of month days were added as suggested by Raghunath et al. (1982). Monthly values are required to obtain the location differences of erosive rainstorms within the year. With monthly rainfall erosivity values a farm manager can determine at which point in his cropping system additional conservation practices would be required to achieve the greatest savings of soil. The monthly erosion index distribution can also be used to evaluate the erosion control effectiveness of specific crop rotations and management practices under specific rainfall pattern of a location. This is in accordance with Ram Babu et al. (2004).

### Estimation of Rainfall and R Values for Yearly Intervals

For obtaining yearly rainfall and EI<sub>30</sub> values, the rainfall and storms EI<sub>30</sub> for that length of period were added i.e. the rainfall and storms EI<sub>30</sub> for the length of 365 days were added as suggested by Raghunath et al. (1982). Yearly values are required to obtain the location differences of erosive rainstorms within the year. The annual EI<sub>30</sub> values are important to find out geographical differences in the ability of average annual rainfall to cause erosion. The annual erosivity index values can be used to determine annual soil loss under specific rainfall pattern. This is in accordance with Ram Babu et al. (2004).

### Computing the Fournier Index

Relationship was established between rainfall erosivity and Fournier Index to assess the factor of rainfall erosivity in the wider area. Fournier Index calculates the annual relative concentration of rain, thus permitting its degree of erosion to be estimated. This is in accordance with Svetlana *et al.* (2002).

$$Fm = 12 \sum_{i=1}^{12} \frac{P_i^2}{P_{ann}}$$

Where:

$P_i$  = precipitation of month  $i$

$P_{ann}$  = total annual precipitation

### Establishing Relation between Yearly & Monthly Rainfall and Yearly & Monthly Rainfall Erosivity

Graphs were drawn between rainfall, rainfall erosivity with a year for Anantapur, Chittoor, Khammam, Nizamabad, Krishna and Visakhapatnam districts to determine as to how the rainfall and rainfall erosivity were varied during the year from 1963 to 1999. The relationship was further scaled down to an average monthly rainfall and its erosivity. This could be used for planning of soil conservation farming. This is in accordance with Ram Babu et al. (2004).

**Table 6: Temporal Relationship between Daily, Weekly, Monthly Yearly Rainfall and their Respective Erosivities (Y: Erosivity; X Rainfall)**

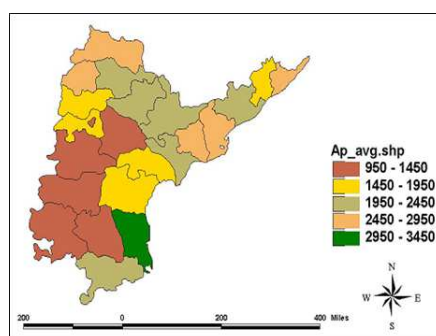
S. No	Districts	Equation for $EI_{30}$				
		Daily	Weekly	Monthly	Yearly	Fournier index
1	Anantapur	$Y = 0.0179X^{2.3491}$ $R^2=0.9724$	$Y = 0.0301X^{2.014}$ $R^2=0.9334$	$Y = 0.0521X^{1.7464}$ $R^2=0.9225$	$Y = 0.0606X^{1.5395}$ $R^2=0.8667$	$Y = 10.642X-289.44$ $R^2=0.6854$
2	Chittoor	$Y = 0.0197X^{2.313}$ $R^2=0.9692$	$Y = 0.0337X^{1.9534}$ $R^2=0.9352$	$Y = 0.0619X^{1.683}$ $R^2=0.9271$	$Y = 0.0552X^{1.5282}$ $R^2=0.8546$	$Y = 17.004X-906.48$ $R^2=0.7408$
3	Khammam	$Y = 0.0212X^{2.2876}$ $R^2=0.9674$	$Y = 0.0387X^{1.8921}$ $R^2=0.9323$	$Y = 0.0943X^{1.5741}$ $R^2=0.9311$	$Y = 0.0761X^{1.4734}$ $R^2=0.8059$	$Y = 12.153X-563.48$ $R^2=0.642$
4	Nizamabad	$Y = 0.0209X^{2.2863}$ $R^2=0.9715$	$Y = 0.0348X^{1.9414}$ $R^2=0.945$	$Y = 0.0867X^{1.5953}$ $R^2=0.9363$	$Y = 0.0363X^{1.5969}$ $R^2=0.8255$	$Y = 15.333X-1479.1$ $R^2=0.7541$
5	Krishna	$Y = 0.0203X^{2.3012}$ $R^2=0.9775$	$Y = 0.0203X^{2.3012}$ $R^2=0.9775$	$Y = 0.0681X^{1.6521}$ $R^2=0.9246$	$Y = 0.0584X^{1.6521}$ $R^2=0.8419$	$Y = 14.654X-774.81$ $R^2=0.6739$
6	Visakhapatnam	$Y = 0.0197X^{2.315}$ $R^2=0.9661$	$Y = 0.0325X^{1.9351}$ $R^2=0.9276$	$Y = 0.0669X^{1.6352}$ $R^2=0.9238$	$Y = 0.2466X^{1.2924}$ $R^2=0.7243$	$Y = 13.466X-517.82$ $R^2=0.569$

## Map Development

In order to apply the results of the present work in relation to rainfall erosivity data and its practical application, a rainfall erosivity map was used. Rainfall erosivity is used to find out the differences in the erosion producing potentials of rainfall patterns in the different parts of the state, a statewide erosion index map is required. So, temporal changes in erosivity factor of Andhra Pradesh state map were prepared. Temporal changes in erosivity factor of different districts of Andhra Pradesh maps were also prepared to find out the differences in the erosion producing potentials of rainfall patterns in the different parts of the districts. Average rainfall erosivity maps were prepared for estimation of spatial assessment.

## Spatial Assessment of Erstwhile State of Andhra Pradesh using Average Annual Erosivity Index Map

Each district of Andhra Pradesh has been represented with respect to average annual rainfall erosivity using different colour codes. The Fig.4 shows that the maximum average annual rainfall erosivity factor for 1 station ranged 2950 to 3450  $tha^{-1}cmh^{-1}$  and the minimum average annual rainfall erosivity factor for 6 stations ranged 950 to 1450  $tha^{-1}cmh^{-1}$ . This is in accordance with Raghunath et al. (1982) and Ram Babu et al. (2004).



**Figure 4: Spatial Assessment of Average Annual Erosivity Factor for the Erstwhile State of Andhra Pradesh**

## Spatial Assessment of Different Districts of Erstwhile State of Andhra Pradesh by using Average Annual Erosivity Index Map

Every station in different districts of erstwhile state of Andhra Pradesh has been represented with respect to average annual rainfall erosivity using different colour codes. The results revealed that spatial assessment of average annual erosivity factor for Anantapur district. It indicated that maximum average annual erosivity factor for 3 stations ranged from 1000 to 1250  $tha^{-1}cmh^{-1}$  and minimum average annual erosivity factor for 15 stations ranged from 250 to 600  $tha^{-1}cmh^{-1}$ . The maximum average annual erosivity factor for 1 station ranged from 4000 to 4500 and minimum average



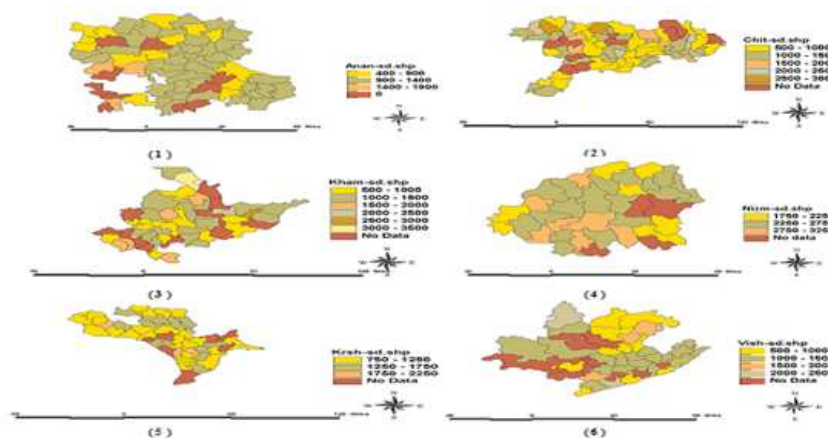
annual erosivity factor for 16 stations ranged from 1000 to 1500  $\text{tha}^{-1}\text{cmh}^{-1}$  in Chittoor district. The maximum average annual erosivity factor for 1 station ranged from 4000 to 4500  $\text{tha}^{-1}\text{cmh}^{-1}$  and minimum average annual erosivity factor for 5 stations ranged from 1500 to 2000  $\text{tha}^{-1}\text{cmh}^{-1}$  in Khammam district. The maximum average annual erosivity factor for 1 station ranged from 2550 to 3050  $\text{tha}^{-1}\text{cmh}^{-1}$  and minimum average annual erosivity factor for 1 station ranged from 50 to 550  $\text{tha}^{-1}\text{cmh}^{-1}$  in Nizamabad district. The maximum average erosivity factor for 2 stations ranged from 3000 to 3500 and minimum average erosivity factor for 9 stations ranged from 1500 to 2000  $\text{tha}^{-1}\text{cmh}^{-1}$  Krishna district. The maximum average annual rainfall erosivity factor for 1 station ranged from 4000 to 4500 and minimum average annual rainfall erosivity factor for 4 stations ranged from 1500 to 2000  $\text{tha}^{-1}\text{cmh}^{-1}$  in Visakhapatnam district. The average annual erosivity factor of the erosivity index map was useful to determine as to how the erosivity varies at different locations in that state/district. This information is used for planning the soil conservation farming. This is in accordance with Raghunath et al. (1982) and Ram Babu et al. (2004).

#### **Spatial Assessment of Erstwhile State of Andhra Pradesh using Standard Deviation of Annual Rainfall Erosivity**

The maximum standard deviation of erosivity factor was 1977  $\text{tha}^{-1}\text{cmh}^{-1}$  occurred in Nellore district and the minimum was 705  $\text{tha}^{-1}\text{cmh}^{-1}$  occurred in Hyderabad district.

#### **Spatial Assessment of Different Districts of Erstwhile State of Andhra Pradesh by Using Standard Deviation of Annual Rainfall Erosivity**

The Figure.5 depicted that spatial assessment of standard deviation of erosivity factor for Anantapur district. In which maximum standard deviation of erosivity factor was 1152  $\text{tha}^{-1}\text{cmh}^{-1}$  occurred in Mudigubba and minimum was 232  $\text{tha}^{-1}\text{cmh}^{-1}$  occurred in Amadaguru. The maximum standard deviation of erosivity factor was 2768 occurred in Thottambedu and minimum was 548 occurred in K. B. Varipalli in Chittoor district. The maximum standard deviation of erosivity factor was 3033 occurred in Cherla and minimum was 622 occurred in Emalur in Khammam district. The maximum standard deviation was 2831 occurred in Navipet and minimum was 96 occurred in Birkoor of Nizamabad district. The maximum standard deviation was 1881 occurred in Avanigadda and minimum was 766 occurred in Chandarlapadu Krishna district. The maximum standard deviation of erosivity factor was 2346 occurred in Munchigupt and minimum was 584 occurred in Kotavurtla Visakhapatnam district. This shows that maximum deviation was occurred in maximum erosivity areas and minimum deviation was occurred in minimum rainfall erosivity areas. This is in accordance with Raghunath et al. (1982) and Ram Babu et al. (2004).



## REFERENCES

1. Arnoldus, H. M. J., 1977. Methodology used to determine the maximum potential average annual soil loss due to sheet and rill erosion in Morocco. *FAO Soils Bulletin* 34, 39–51.
2. Brown, L. C., and Foster, G. R. (1987). Storm erosivity using idealized intensity distributions. *Transaction of the ASAE.*, **30** (2): 379-386.
3. De Ploey, J., Kirkby, M., Ahnert, F., 1991. Hillslope erosion by rainstorms – a magnitude – frequency analysis. *Earth surface processes and landforms* 16, 399–409.
4. Grimm, M., Jones, R. J. A., Rusco, E., Montanarella, L., 2003. Soil erosion risk in Italy: a revised USLE approach. *EUR 20677 EN, Office for Official Publications of the European Communities, Luxemburg, Luxemburg*, p. 26.
5. Raghunath, B. and Erasmus, I. I. (1971). A method for estimating erosion potential from daily rainfall. *The Indian Forester.*, **97**(3): 121-125.
6. Raghunath, B., Khullar, A. K. and Thomas, P. K. (1982). Rainfall energy map of India. *Indian J. Soil Cons.*, **10** (2): 1-17.
7. Ram Babu, Dhyani, B. L. and Nirmal Kumar. (2004). Assessment of erodibility status and refined iso-erodent map of India. *Indian J. Soil Cons.*, **32** (3): 171-177.
8. Renard, K. G., Freimund, J. R., 1994. Using monthly precipitation data to estimate the R-factor in the revised USLE. *Journal of Hydrology* 157, 287–306.
9. Svetlana, B., Tomislav, S., and Sonja. B. (2002). Definition of rainfall erosivity in the area of the experimental station Snagovo. *Institute of Forestry*, p.190-196.
10. Torri, D., Borselli, L., Guzzetti, F., Calzolari, C., Bazzoffi, P., Ungaro, F., Bartolini, D., Salvador Sanchis, M. P., 2006. Soil erosion in Italy: an overview. In: Boardman, J., Poesen, J., (Eds.), *Soil Erosion in Europe*. Wiley and Sons, Chichester, UK, pp. 245–261.
11. Yu, B., Hashim, G. M., Eusof, Z., 2001. Estimating the R-factor with limited rainfall data: a case study from peninsular Malaysia. *Journal of Soil and Water*

